# Los Alamos
**National Laboratory**
Los Alamos, New Mexico 87545

# SUBCONTRACT AWARD/ PURCHASE ORDER MODIFICATION

***ORDER NUMBER MUST APPEAR ON OUTSIDE OF EACH PACKAGE AND ON ALL SHIPPING PAPERS AND INVOICES***



**CONTRACT AWD/PO NO.**
72232-001-03 3U

**MODIFICATION NO.**
2

*Operated by the Regents of the University of California under Government Contract No. W-7405-ENG-36 Dated January 1, 1943*

| AWARD/CONFIRMATION DATE | EFFECTIVE DATE | FUNDED AMOUNT | CEILING AMOUNT | CONTRACT TYPE |
|---|---|---|---|---|
| 30 Jun 2003 | 08 Sep 2004 | $1,272,000.00 | $.00 | Intra-Univ Transaction |

| ISSUED BY | TELEPHONE | FAX | EMAIL |
|---|---|---|---|
| WARREN FINCH | (505) 667-3702 | (505) 667-1219 | finch_warren_w@lanl.gov |
| **ADMINISTERED BY** | **TELEPHONE** | **FAX** | **EMAIL** |
| DEBRA CARLISLE | (505) 665-2431 | (505) 665-8803 | dac@lanl.gov |

**SUBCONTRACTOR**
UNIV OF CALIFORNIA/SAN DIEGO
9500 GILMAN DR DEPT 0934
LA JOLLA, CA 920930934

Phone: (858) 534-0243

**CONFIRMED BY:**
Carlisle/Farrar 30 Jun 2003

**QUOTED BY:**
Lynelle A Gehrke 30 Jun 2003
Quote #: 2003-8152-Rev 1

**SHIP TO**
Los Alamos National Laboratory
Bldg SM30 Bikini Atoll Road
Los Alamos, NM 87545
REF: 72232-001-03 3U

**INVOICE TO**
**Invoice must be mailed to:**

Los Alamos National Laboratory
P.O. Box 1663
ATTN: Accounts Payable, M/S P240
Los Alamos, NM 87545
REF: 72232-001-03 3U

**INVOICE TERMS:**
NET 30 DAYS
Term begins from receipt of goods or receipt of invoice in Accounts Payable, whichever is later.

**MODIFICATION REASON**

Modification No. 2 is written to change our Memorandum Agreement in the following particulars only:
1. Add line item 4, Phase II, increase funding level by $632,000.00, increase total cost of order to $1,272,000.00.
2. Extend period of performance to 09-30-05 on line item(s) 1 through 3.
3. Change "Invoice Approver" to Chuck Farrar-LANL UTR.
4. Change Appendix A - Statement of Work - to add Phase II.

The Subcontractor agrees to furnish and deliver all items or perform all services identified in this subcontract for the consideration stated herein. This subcontract expressly limits acceptance to the terms referenced herein and/or attached hereto, and any additional or different terms proposed by the Subcontractor are rejected unless expressly assented to by the University in writing.

**ACKNOWLEDGEMENT - PLEASE SIGN AND RETURN PROMPTLY TO:**
WARREN FINCH M/S D442
P. O. Box 1663
Los Alamos, NM 87545

| For the Subcontractor | For The Regents of the University of California |
|---|---|
| **Vendor's Reference Number** | |
| **Name and Title** (Type or Print) | **Name and Title** (Type or Print) |
| **By** | **By** |
| (Signature of person authorized to sign) **Date Signed** | (Signature) **Date Signed** |

**Line Items Continued on Next Page**

**Los Alamos**
**National Laboratory**
**Los Alamos, New Mexico 87545**

# SUBCONTRACT AWARD/ PURCHASE ORDER MODIFICATION

*ORDER NUMBER MUST APPEAR ON OUTSIDE OF EACH PACKAGE AND ON ALL SHIPPING PAPERS AND INVOICES*



**SUBCONTRACT AWD/PO NO.**
72232-001-03 3U

**MODIFICATION NO.**
2

*Operated by the Regents of the University of California under Government Contract No. W-7405-ENG-36 Dated January 1, 1943*

| ITEM | DESCRIPTION | QUANTITY | UNIT ISSUE | UNIT PRICE | EXTENSION | DELIVERY |
|---|---|---|---|---|---|---|
| 0001 | Phase I-Task 1<br>Engineering Institute Fellowship and Joint Educational Program.<br><br>Reference: Memorandum Agreement<br>Appendix A-UCSD Statement of Work/Deliverables-Revision 1<br>Appendix B-Payment Schedule<br><br>PERF. PERIOD: 31 Jul 2003 to 30 Sep 2005<br>FOB: Not Applicable or Requird<br>SHIP VIA: N/A (no freight involved) | NOT | TO | EXCEED | $344,400.00 | 30 Sep 2005 |
| 0002 | Phase I-Task 2<br>Collaborative UCSD/LANL effort on Predator damage prognosis and reliability.<br><br>Reference Memorandum Agreement<br>Appendix A-UCSD Statement of Work/Deliverables-Revision 1<br>Appendix B-Payment Schedule<br><br>PERF. PERIOD: 31 Jul 2003 to 30 Sep 2005<br>FOB: Not Applicable or Requird<br>SHIP VIA: N/A (no freight involved) | NOT | TO | EXCEED | $130,000.00 | 30 Sep 2005 |
| 0003 | Phase I-Task 3<br>Collaboration between UCSD and LANL on effort to monitor structural integrity of structural joints.<br><br>Reference Memorandum Agreement<br>Appendix A-UCSD Statement of Work/Deliverables<br>Appendix B-Payment Schedule<br><br>PERF. PERIOD: 31 Jul 2003 to 30 Sep 2005<br>FOB: Not Applicable or Requird<br>SHIP VIA: N/A (no freight involved) | NOT | TO | EXCEED | $165,600.00 | 30 Sep 2005 |
| 0004 | Phase II<br>Analysis and Identification of Machine Tool Chatter, Diagnosis and Prognosis of Resin Infused Composites Subject to Process and Impact Damage.<br><br>Deliverables will be in accordance with Appendix B Revised SOW.<br><br>PERF. PERIOD: 01 Sep 2004 to 30 Sep 2005<br>FOB: Not Applicable or Requird<br>SHIP VIA: N/A (no freight involved) | NOT | TO | EXCEED | $632,000.00 | 30 Sep 2005 |
| | | | | **TOTAL CONTRACT AMOUNT** | | **$1,272,000.00** |

**Agreement 72232-001-03 between Los Alamos National Laboratory, hereinafter called the "University", and the University of California at San Diego, hereinafter called the "Campus" is modified as described herein. Except as modified, all other terms and conditions remain unchanged and in full force and effect.**

**This modification consists of nine (9) pages.**
**Description of Modification:**

**1. Change the content of Article 1 – "SCOPE OF WORK", in its entirety as follows:**

"The services to be provided under this Agreement shall be in accordance with item description in Appendix A, Phase I-UCSD Statement of Work/Deliverables-Revision 1, Phase II-Appendix B, UCSD Statement of Work. This Statement of Work may be modified by mutual agreement of the parties to this agreement."

**2. Change the content of Article 2 – "TERM", in its entirety as follows:**

"The term of this Agreement shall be Upon Signature through September 30, 2005, unless extended by mutual agreement or terminated in the accordance with Article X entitled Termination. Except as necessary to comply with any reporting and closeout procedures, Campus shall discontinue performance of work on the last date cited above unless Laboratory extends the period of performance by written notice to Campus, as agreed upon by both parties."

**3. Change the content of Article V – "EXPENDITURES", in its entirety as follows :**

**Revised 09-01-04**

| | **Phase I** | **Phase II** |
|---|---|---|
| Direct Labor | $157,751. | $283,958. |
| Fringe-Students | $ 37,811. | $ 18,489. |
| Travel | $ 18,850. | $ 25,425. |
| Other Direct Costs | $570,311. | $264,256. |
| Indirect Costs | $ 69,689. | $ 47,872. |

The current estimated cost of work to be performed under this Agreement is $1,272,000.00

A. Limitation of Funds - The amount presently available for payment by the University and allotted to this Agreement for all items of Phase I as listed in Section V is $640,000.00. It is estimated that this amount is sufficient to cover performance by the University of California/San Diego Campus, through September 30, 2004 which has now been extended to 09-30-2005 with this action. Modification No. 2 is written to increase funding by $632,000.00 for Phase II, the remaining funds will be increased in FY05 with a period of performance through September 30, 2005.

B. No costs incurred prior to the start date of this Agreement as stated above in Article II are authorized. Campus shall not incur costs and Laboratory shall not be obligated to make any payments under the Agreement in excess and waive any right to such cost of the amount obligated in the absence of a written modification or notice from Laboratory authorized personnel named in Article XII.

C. If, and to the extent the amount obligated by Laboratory is increased, any costs Campus incurs before the increase that are in excess of the amount previously obligated shall be allowable upon Laboratory approval to the same extent as if incurred afterward.

4. Change Appendix A – Statement of Work to add Phase II as follows :

**"Appendix A**
**Phase II: UCSD Statement of Work**
Page 1

**Los Alamos National Laboratory-University of California San Diego**
**Graduate Fellowship Program**
**Phase II**

This proposal expands upon a contract between Los Alamos National Laboratory (LANL) and the University of California San Diego (UCSD) to develop and support an Educational Fellowship Program between the LANL Weapons Engineering and Manufacturing Directorate and the UCSD Jacobs School of Engineering. Established as a multi-year research-based educational initiative, the activities proposed are for the period September 1, 2004 through September 30, 2005.

The LANL-UCSD Fellowship Program will focus on Damage Prognosis Technology. The proposal develops further the educational program envisaged for these students. The classroom educational focus of the program is a multidisciplinary approach to engineering simulations with an emphasis on validated numerical simulations and structural health monitoring for Damage Prognosis. Courses will be taught at both UCSD and LANL by UCSD faculty and LANL staff that will become UCSD adjunct faculty pursuant to appropriate UCSD policies. The applied learning will take place under the supervision of UCSD faculty and LANL personnel on research critical to LANL's mission. The degree will employ a multidisciplinary curriculum focusing on the integration of predictive modeling, experimental diagnostics, and data interrogation culminating in a project-oriented capstone course on model validation and uncertainty quantification, or structural health monitoring. Currently, no other institution offers a degree that combines these particular areas. Other educational programs offered by this Institute will be the Los Alamos Dynamics Summer School, short courses and possibly an industry-focused training program in the area of structural dynamics.

To continue substantial interaction between LANL researchers and UCSD, LANL will support four additional fellowships in the 2003-2004 year. Every effort will be made to identify U.S. citizens and/or permanent residents for these fellowships. These fellowships are intended to recruit and provide unique educational experiences to the brightest graduate students in the area of Engineering Systems Analysis for Reliability and Damage Simulation and Prognosis. As part of the overall educational experience, students are expected to spend some amount of time at LANL working on research, and to thereby avail themselves to the specialized facilities in those laboratories. This will also provide opportunities for these students to interact closely with top scientists and engineers at LANL who are doing cutting-edge research in the areas of focus.

In addition this contract will provide funding support for the lease of space at the Los Alamos Science Research Park for educational and research activities. A great amount of effort still remains in the development of joint courses and in bringing the proposed degree program to the point where they may be submitted for administrative approval through proper channels at UCSD. In addition, administrative support is critical to the development and execution of lease provisions, logistics of course offerings, clarifying faculty participation and credit, and defining the appropriate level of student engagement at each location. CVs of potential adjunct faculty in Structural Engineering are being prepared and will be considered this year. Courses for the proposed program are being developed and schedules are being established for offering courses in the program.

**Appendix A**
**Phase II: UCSD Statement of Work**
Page 2

The educational program is envisioned to be technology-driven and research-based. In order to provide the unique educational experience to the fellowship holders and to facilitate their education in this emerging area of Damage Prognosis Technology, emphasis will be placed in four primary areas 1) reliability of composite materials used in unmanned vehicles, 2) the structural integrity of metal to composite joints, 3) analysis and identification of machine tool chatter, and 4) manufacturing-induced critical defect identification in composite materials. Each of these provides an educational test-bed for development and validation of simulation and prognosis tools and will facilitate synthesis of information learned in the classroom as well as advance the state of the art. Thus the students will have the benefit of engineering applications while pursuing education and research at a fundamental level.

Unmanned Aerial Vehicles (UAV) Damage Prognosis and Reliability

UAVs are being used by the military for surveillance and by the scientific community for a variety of surveying and monitoring applications. The vehicles are typically made of lightweight advanced composite materials to reduce their weight and improve their performance (longer flight times). Upon landing, these vehicles must be quickly inspected and maintained before being sent back on another mission. Without a pilot, there is very little known about the in-flight performance or any problems except what may be concluded from its few autopilot sensors. What is needed is a system that will monitor the composite airframe (wings, fuselage, and empennage), assess its structural integrity, identify a maintenance schedule, and predict the remaining life of critical components (prognosis). Both LANL and UCSD will work together on system development. This system, which could either be an in-flight on-line system or a preflight modal/acoustic test, would monitor stiffness changes (flutter prevention), strength reductions (fatigue), or ballistic damage. The system sensors could either be attached (piezoelectric patches, accelerometers, resistive strain gages) or embedded (fiber optics), and it could be passive (sensors only) or active (sensors and actuators). This sensor data along with reduced-order analytical methods will be used to identify regions in the structure that need further inspection. In order to predict the remaining component life, one needs a robust analytical structural model that correctly accounts for geometric and material uncertainties, and the uncertainties associated with current and future loadings and sensor measurements. Methods used in structural reliability (uncertainty) analysis that will be investigated include Monte Carlo simulation, importance sampling, Bayesian updating, First- and Second-Order Reliability Methods (FORM and SORM), and finite element reliability analysis,

Structural Joint Integrity Monitoring and Assessment

The use of heterogeneous materials in aggregate structural systems is increasing for a number of applications where performance demands and/or cost considerations warrant such hybrid designs. For example, the U.S. Navy is considering such a hybridized design for the next generation destroyer DD-X surface ship, which has a composite material superstructure and a metal hull. Such a design involves many metal-to-composite bolted connections. Under normal in-service mechanical and thermal stresses, composite materials are known to creep over time, resulting in loss of pre-load at the connection. This pre-load loss leads to reduced functionality in the joint to support design loads and can ultimately lead to catastrophic failure through wear, fatigue, or stress rupture. Currently, the inspection and re-torquing of bolted connections is performed by rote schedule without regard to condition, but as the U.S. Navy officially transitions to a condition-based maintenance philosophy, an on-line, automated diagnostic condition assessment is needed to meet these new requirements.

**Appendix A**
**Phase II: UCSD Statement of Work**
Page 3

This need is further strengthened as a large manning reduction of up to 70% is expected to accompany the DD-X program. The primary goals for UCSD students assigned to this task are (1) to identify the relevant time-frames for the creep-induced pre-load loss and subsequent failure mechanism(s) of these bolted connections; (2) to identify an appropriate diagnostic test or tests that can track these processes; (3) to identify an appropriate sensor system to obtain the proper measurements needed to complete the diagnostic test(s); (4) to develop predictive models and couple them with the diagnostic analysis and real-time loads monitoring for prognostic capability; and (5) ultimately, to develop and deliver a prototype fastener degradation diagnostic/prognostic system meeting U.S. Navy requirements in condition-based maintenance. Students that develop the signal processing, nonlinear dynamics, tune-dependent plasticity material behavior, and statistical pattern recognition capabilities necessary to complete this task will have the technical background to directly impact LANL programs such as the advanced material modeling and data interrogation associated wit our high-fidelity predictive modeling efforts that supports almost all large-scale nuclear weapons engineering programs and the pit manufacturing program.

Analysis and Identification of Machine Tool Chatter

Friction and other nonlinear contact mechanisms between cutting tools and specimens may lead to the onset of broad-band impact dynamics under certain conditions. This dynamic condition causes degradation of the cutting process, which must be maintained to very tight tolerances for weapons-related manufacturing applications. The condition also ultimately may lead to tool degradation and failure. Currently, no on-line technique able to detect the onset of chatter exists, and operations procedures at Los Alamos National Lab require shutdown of the cutting process if chatter is detected at all (e.g., through an observation of cutting degradation). The students assigned to work in this task will be developing and implementing advanced methods in vibration analysts such as wavelets, nonlinear time series, non-stationary stochastic models, and nonlinear system identification (e.g. ARMA) to analyze and identify machine tool chatter. The primary goals for the students are (I) to identify the onset of machine tool chatter from experimental data obtained from LANL cutting shops; (2) to develop an automated algorithm for identification by integration with existing measurement capability; (3) if desired, to integrate identification with control, as per LANL operations procedures; and ultimately, (4) to specify and deliver a software/hardware solution for on-line detection and control of chatter.

Diagnosis and Prognosis of Resin Infused Composites Subject to Process and Impact Damage

The structural performance of fiber-reinforced polymer composites is highly dictated by the particular conditions of the manufacturing process followed, more so than in the case of more traditional metal-based materials. The inherent variability in process conditions often results in a stochastic-based, rather than deterministic-based knowledge of the structural properties of the finished product. It is critical to be able to detect, identify and quantify critical defects during manufacturing and monitor their evolution in service to determine the remaining life of a damaged structure. This process requires linking defect diagnostics to the performance/life curve of the structure. Defect diagnostics and monitoring is particularly relevant for low-cost, autoclave-free manufacturing methods used to fabricate large parts such as in marine, naval and civil engineering applications.

**Appendix A**
**Phase II: UCSD Statement of Work**
Page 4

Although significant work has been done in the areas of (a) Composites Processing Science and (b) deterioration science of the resulting material, there is a critical gap in the integration of these areas to allow for prediction of effects of process variables and defects occurring thereof on the overall integrity of low cost (or rather lower-cost as compared to prepreg based autoclave technology) composite structures. Processes such as resin infusion, are being actively considered by the Navy for future vessels, are currently used in limited amounts on aircraft, and are being considered in the next generation combat vehicles by the army. Prediction of service-life and damage prognosis depends intrinsically on the knowledge and understanding of the processing and deterioration science of these materials and the development of an effects of defects methodology. In an integrated system sensors placed in the perform would allow monitoring and in-line correction during processing, while also serving as a sensing system during its service-life (such as to monitor changes in local stress state due to damage).
The diagnosis of the "health" or integrity of the structure following damage, such as through impact, is critical to the use of these materials. The availability of a variety of fabric structures makes it possible to "design" for specific threats. However, at the present time there is limited understanding on remaining life and residual performance characteristics following such events. The development of a prognosis tool in this case requires a good understanding of the original material state and the defects already existing therein (such as delaminations between layers, large voids, dry spots, resin rich zones etc) which serve as initiation points for further damage accrual following impact. Further process related conditions such as under- or over-cure, shrinkage and residual stresses will also affect these systems and their performance after impact, especially in areas of stress concentration such as holes, bolted joints etc.

The proposed task would address the following aspects:

- Fundamental understanding of process induced defects and effects on performance and integrity to enable development of validated simulations
- Assessment of sensing methods for combined process and performances monitoring
- Development of methodologies to assess post-impact damage state and residual life/performance characteristics of the material

The research would combine expertise in process modeling (solid and flow), durability, damage detection and then prognosis in the development of an experimentally validated system that integrates both heuristic knowledge with simulations to allow for prognosis of impact damage on performance. The emphasis will be on the development of a system that accounts for pre-impact material state as the base-line rather than one that assumes a perfect, defect-free material. This will provide a more valuable and correct tool for service-life prediction since it is built on the assumption of a continua from processing through use.

The proposed research area also augments work initiated in the field of creep of bolted joints while simultaneously addressing two areas of Damage Prognosis/Validated Simulations and Materials Science which are LANL thrusts.

**Appendix A**
**Phase II: UCSD Statement of Work**
Page 5

| **Fellowship Development and Administration:** UCSD Faculty: Frieder Seible, Michael Todd, and Vistasp Karbhari; LANL Collaborators; Charles Farrar, Steven Girrens | Due Date (Days after contract award) |
|---|---|
| a. Establish procedures for continued and new fellowship appointments | 90 |
| b. Submit paperwork required for Departmental Approval of program; forward to UCSD Academic Senate for approval of degree in Engineering Sciences, Systems Engineering Analysis in Damage and Reliability Simulation and Prognosis. | 120 |
| c. Submit paperwork to Graduate Council for program approval. | 180 |
| d. Organize processes necessary for leasing space | 240 |
| e. Investigate further mechanisms for delivering coursework to students both at UCSD) and at Los Alamos | 270 |
| f. Establish requirements for student research location and test feasibility. | 360 |
| **Educational Focus on UAV Damage Prognosis and Reliability**; UCSD Faculty: Prof. J. Kosmatka, Prof. J. Conte, and Prof. F. Lanza di Scalea LANL Collaborators: Dr. M. Anderson, Dr. F. Hemez, Dr. G. Park, and Dr. I. Beyerlein | |
| a. Procurement of MTS actuator for wing static/fatigue testing and associated equipment | 90 |
| b. Design and analyze composite wing sub-section | 120 |
| c. Fabricate tooling for composite wing subsections. | 150 |
| d. Fabricate 5 composite wing subsections with different levels of embedded sensors | 210 |
| e. Test static/fatigue of composite wing subsections | 300 |
| f. Deliver report of post-test evaluation of tests specimens, | 360 |
| **Educational Focus on Structural Joint Integrity Monitoring and Assessment**: UCSD Faculty: Prof. M. Todd; LANL Collaborators: Dr. H, Sohn, Dr. M. Bement, Dr. G. Park, Dr. F. Hemez | |
| a. Laboratory evaluation of fiber optic and piezoelectric sensor technologies and provide written brief of applicability for data acquisition | 180 |
| b. Deliver summarization of creep and failure mechanisms in appropriate written report. | 180 |
| c. Determine and evaluate, initially-identified vibration-based feature(s) that track the connectivity degradation in the assembly and report findings. | 180 |

**Appendix A**
**Phase II: UCSD Statement of Work**
Page 6

d. Deliver initial finite element model of bolted assembly.

**Educational Focus on Analysis and Identification of Machine Tool Chatter**; 360
UCSD Faculty: Prof.P. Krysl and Prof. M.D. Todd; LANL Collaborators: Dr. M. Bement

a. Deliver LANL data from tool cutting processes with known chatter occurrences. 30-60
b. Report on literature review of machine tool chatter processes including contributions from finite element, nonlinear dynamics, and rotating machinery areas 180
c. Deliver written report summarizing major data interrogation approaches applied to the data, including (but not limited to) wavelet analysis, ARMA modeling, nonlinear time series analysis, etc 360

**Educational Focus on Diagnosis and Prognosis of Resin Infused Composites Subject to Process and Impact Damage**
UCSD Faculty Prof. V. Karbhari and Prof. G. Hegemier; LANL Collaborators; Dr. I. Beyerlein, Dr. T. Williams, Dr. F. Hemez

a. Report on detailed literature review and assessment of SOTA or resin infusion, with emphasis on process variables, defects, and characterization. 120
b. Deliver preliminary assessment report of techniques for in-situ determination of defects. 210
c. Develop and deliver experimental plan to assess defects and effect on performance. 240
d. Report on experiments to assess significant process variables and review of methods for control of process, and development of plan for integration simulation with heuristic based knowledge base for diagnostics. 360